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Resurgence and flank failure of Mt. Epomeo, Ischia Island (Southern Italy)

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Riassunto

Risorgenza e collasso laterale del Monte Epomeo, Isola d'Ischia

Il Monte Epomeo (787 m a.s.l.), ubicato nel settore centrale dell'isola d'Ischia, mostra lo smantellamento del settore meridionale, depositi di debris e franamenti diffusi che testimoniano la natura instabile del monte. A seguito dell'eruzione ignimbritica del Tufo Verde dell'Epomeo (55.000 anni), che genera una struttura calderica (10x7 km^2), inizia la risorgenza della caldera fino alla formazione del Monte Epomeo. Il sollevamento, generato dall'intrusione di un laccolite fino a circa 1 km di profondità, avrebbe determinato una forte instabilità gravitativa del blocco risorgente e prodotto uno o più collassi laterali. Questi hanno lasciato una struttura a ferro di cavallo, tipica di processi da "avalancing", aperta verso sud, e depositi con topografia "hummocky" estesi a sud dell'Epomeo e rilevati recentemente da esplorazioni sul fondo marino. Il processo che ha generato il collasso e la formazione di un avalanche caldera è stato esaminato attraverso l'analisi della dinamica e dei caratteri geologici, geomorfologici e strutturali dell'area. Attualmente l'isola è caratterizzata da una fase di stasi della risorgenza testimoniata da una condizione di moderata stabilità dei versanti dell'Epomeo. Quanto osservato indicherebbe una bassa dinamica endogena nell'isola.

Key words: *Ischia Island, flank collapse, resurgence caldera, avalanche caldera, laccolith.*

INTRODUCTION

A horseshoe-shaped structure, with deposits of debris and hummocky topography was noted at Mt. Epomeo in the island of Ischia (Southern Italy) (Fig.1). These features have been related to the occurrence of avalanches processes which involved the southern sector of the island during the Mt.Epomeo uplift (Luongo *et alii*, 1995; Tibaldi & Vezzoli, 2004; Carlino *et alii*, 2006; De Vita *et alii*, 2006). The Mt. Epomeo, located in the central part of the island, is a nearly square structure correlated to the resurgence within a roughly 10x7 km^2 caldera. The edges of Mt. Epomeo structure are marked by NW-SE, NE-SW and N-S systems of structurally significant faults and fractures while its uplift probably occurred in fits and starts as inferred partly from the formation and age of marine terraces. We interpreted the uplift of Mt. Epomeo as due to an increase in pressure of a laccolith, located in the shallow crust, rising up to 1 km depth in the centre of the island which triggered the caldera resurgence (Carlino *et alii*, 2006).With the onset of the failure of the block, faults were generated and the uplift along the faults started.

This process produced a progressive gravitative instability of the Mt. Epomeo block and its flank collapse, also promoted by other factors such as earthquakes, hydrothermal rocks alteration, magma intrusion at very shallow depth.

In this study, our aim is to understand the processes generating the flank failure of Mt. Epomeo, by integrated analysis of the morphology and tectonic features of the resurgent area, using 3D terrain model, and geological and geophysical data.

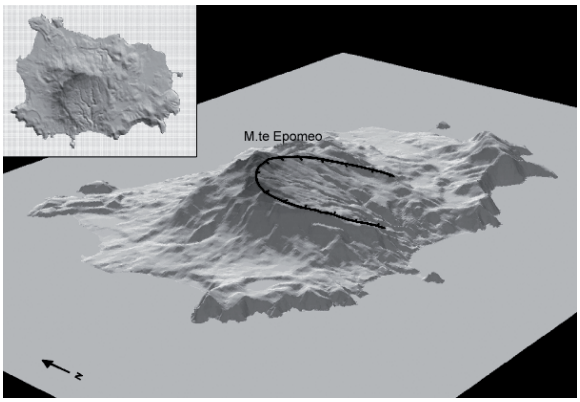

Fig. 1 – Digital Terrain Model of Ischia Island. The dark line highlights the horseshoe-shaped structure of the Mt. Epomeo.

MORPHOLOGICAL FEATURES OF MT. EPOMEO AND AVALANCHES DEPOSITS

The horseshoe-shaped morphology of Mt. Epomeo open towards the southeast, and the large hummochy deposits of the southern coast of Ischia, recently recognized by marine surveys, are consistent with avalanche processes which involved the summit of the Mt.Epomeo resurgent block and the southern onshore caldera flank (Luongo *et alii*, 1995; Tibaldi & Vezzoli, 2004; Chiocci & De Alteris, 2006). The collapse produced an avalanche caldera with a diameter of about 4 km along the NE-SW axis. Generally, the sidewalls of the avalanches calderas are sub-vertical, reflecting the influence of the crater walls (Sibert, 1984). The absence of a crater structure on the Mt. Epomeo did not generate this kind of morphology

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(Fig.2). Toward southern coast (Maronti) a series of closely valley and little hills (hummocky topography) and an hydrographic grid with dentritic structure was observed. The deposits which covered the southern sector of the Mt. Epomeo are generally poorly sorted and formed by lithic material, crushed fragments of tuff forming a matrix and large blocks of Green Tuff. The maximum thickness of these deposits is about 200 meters covering an area of about 4 km^2. The main sub-aerial debris avalanche deposits have been recognized in the interval 8.600-5.700 years B.P. (Tibaldi & Vezzoli, 2004).

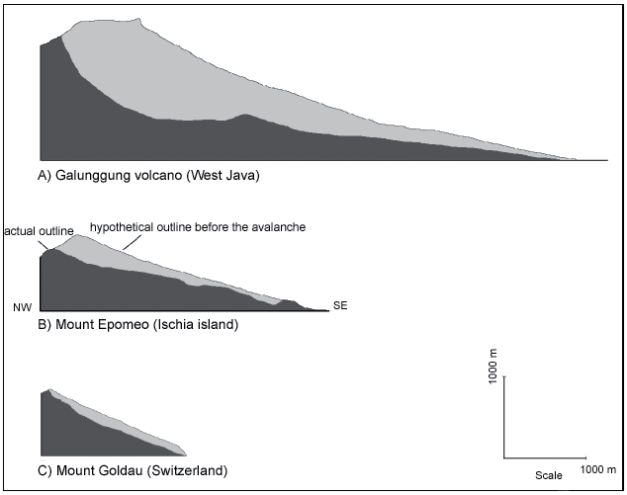

Fig. 2 – Comparison among different cross-section of avalanche caldera. (A) Galunggung volcano, (B) Mount Epomeo (C) Mount Goldau non volcanic landslide (C). The section of the Mt. Epomeo is along NW-SE direction.

Debris avalanches deposits, inferred by marine geophysical data, have been also found in the southern offshore, as far as 40 km of distance from the source area, with a volume of 1-3 km^3 (Chiocci & De Alteris, 2006). Considering these deposits as products of Mt.Epomeo dismantlement, we found an H/L ratio of 0.05, which is equivalent to the apparent coefficient of friction during the sliding (Siebert, 1984). The H/L low ratio of Ischia debris avalanche shows a great mobility (low friction), probably due to the weak hydrothermally altered rocks and to the fluidization for the immersion into the sea water. H/L ratio of about 0.04 have been found at Colima and Citlatèpetl volcanoes (Mexico) where a diffuse hydrothermal system, similar to that of the source area of Ischia debris avalanches, occurs. Furthermore, the present volume of Mt. Epomeo resurgent block is about 8 km^3. Assuming the not-deformed resurgent block (before the avalanche) as a cylinder with a ray of 2 km and 800 meter high, the difference between the volume before and after the avalanche is about 2-3 km^3, the same magnitudes of debris avalanches deposits.

THE POTENTIAL CAUSES OF MT. EPOMEO FLANK COLLAPSE

The causes of the flank failure are not yet fully understood, and probably different factors have contributed to the type and orientation of dismantlement. The orientation of the caldera is probably influenced by the regional stress field, which shows the maximum tensile component towards NW-SE, in the same direction of the caldera avalanche opening. At Ischia the source of deformation processes involving the Mt. Epomeo can be associated to the dynamics of a shallow laccolith whose pressure increment produces the resurgence of a roughly 4x4 km block, along a system of NW-SE, NE-SW and also N-S faults. Along these faults, in the northern sector, seismic sources were localized since 1228 (Carlino *et alii*, 2006).

The block uplift, which occur at an average velocity of 3.3 cm a^{-1}, was accompanied by volcanic activity and lava dome emplacement around the resurgent block. The relative fast uplift and the magma intrusion have contributed to produce high slope angles on the flanks of the Mt. Epomeo and their instability. Other factors have probably contributed to the trigger of the avalanches, such as:

- earthquakes, which occurred frequently in the island;
- the hydrothermal system, widely diffused in the island, which produced thermal alteration and weakened of the overlying rocks.

The failure of Mt. Epomeo was followed by the decompression of magmatic system which produced an explosive eruption. In fact, the loss volume due to the avalanche produced a decrease in lithostatic load of about 5 MPa which represent a typical threshold of explosive eruptions due to rapid decompression (Alidibirov & Dingwell 1996; Carlino *et alii*, 2006). The present state of the island is characterised by the stasis of the resurgence and lack of seismic and eruptive activity which reduce the possibility of further collapse of the Mt. Epomeo. A reactivation or increase of the dynamic of the shallow magmatic body due to the arrival of new magma might generate new large episodes of gravitational instability.

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